VITAL AND MONETARY LOSSES DUE TO PREVENTABLE DEATHS

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VITAL AND MONETARY LOSSES IN THE UNITED STATES DUE TO PREVENTABLE DEATHS.

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The purpose of this paper is to set forth the results of a statistical investigation of the vital and monetary losses in this country due to the occurrence of preventable deaths; to show (a) to what extent the average length of human life is affected by the occurrence of such deaths; (b) the effect on the expectation of life, or average future life time, at any age; (c) the effect on the death rate, at any age; (d) how great a monetary loss is sustained through such a death, assuming that the life of every person has a value, or that during the most productive period of his life—say from the age of twenty to seventy years—every person contributes something annually to the wealth of the community in which he lives; and (e) the total value of these losses, estimated for each age for both males and females, for the whole country.

We have obtained the results set forth in this paper through the comparison of mortality tables which we have constructed and which are based upon the different sets of conditions and hypotheses that are to be introduced and discussed; and a familiarity with what is involved in a mortality table and the expectation of life is so essential to the complete understanding of what follows that we shall now explain briefly what these terms imply.

A mortality table is first of all a table of death rates computed for the different ages of human life. In addition it also exhibits the effects of these death rates upon an arbitrarily chosen community in the following manner. First, a large number of persons is assumed to be living at exactly the same age, usually at the age of birth; then the number of deaths for this age is ascertained by multiplying the number living at the age by the corresponding death rate; and, finally, the difference between the number living, or population, and the number of deaths gives the population at the next higher age. The populations at all the other and higher ages are

found successively in the same way. If we let l_x represent the population or the number of persons living at age x, d_x the number of deaths and q_x the death rate, the mortality table would appear as follows:

Age.	Population.	Deaths.	Death Rate.
0	l_0	d_0	q_0
1	l_1	d_1	q_1
2	l_2	d_2	q_2
x	l_x	d_x	q_x
x+1	l_{x+1}	d_{x+1}	q_{x+1}

where, as explained above, $l_{x+1} = l_x - d_x$

Such a table not only shows at what age the last survivor dies but also provides a means of computing the average future life time or expectation of life. Thus a mortality table based upon the death rates known to exist in a given community sets forth concisely and clearly the mortality conditions of that community, and the mortality conditions of any number of communities are very easily and readily compared by means of such tables.

Obviously, all those that survive from any year of age to the next have each lived one year; hence, if we add together the survivors of all ages beyond any particular age we shall obtain the total number of years lived by those at that age; and, finally, if we divide this total number of years by the population at the age considered we shall obtain the average future life time or expectation of life of persons at that age.

Since a death is just as apt to occur at one time in the year of death as another it is usually assumed that a person will, in the long run, live a half year in the year of death, and this one half of a year is added to the average future life time explained above to obtain what is called the complete expectation of life. Expressed symbolically, the complete expectation of life at age x, or

$$\mathring{e}_x = \frac{1}{2} + \frac{l_{x+1} + l_{x+2} + l_{x+3} \div - -}{l_x}$$

Some of the general though important aspects of the subject under discussion have been investigated by means of short-cut methods. The use of mortality tables, however, has two decided advantages over the short-cut methods; its accuracy insures greater confidence in the results; and the results are given for each age, whereas those of the short-cut methods are given only for the age of birth.

In preparing this paper we constructed a mortality table (Table I) based upon the actual death rates found to exist at the present time in those sections of the United States where reasonably accurate mortality statistics are available. We then constructed another mortality table (Table II) based upon mortality conditions that would exist if preventable deaths were actually prevented. A comparison of these mortality tables forms the basis of our discussion of the vital and monetary losses due to preventable deaths.

It is practically impossible to give a rigid definition of a preventable death. Even if it were possible to know all about the various causes of death, different viewpoints would lead to different decisions as to the preventability of most deaths. Instead of trying to define a preventable death in such a way, we have made use of a set of ratios or percentages collected and arranged by Professor Irving Fisher of Yale University, who sent a list of ninety diseases to each of a group of the most prominent medical authorities in this country and asked them to designate what per cent. of the deaths due to each disease they considered preventable.

To quote from Professor Fisher:* "Since the word 'preventable' implies the hypothesis of different conditions from those which actually exist it is necessary to specify what hypothetical conditions shall be implied in the term. Doubtless tuberculosis would be over 99 per cent. preventable if we should conceive as our hypothetical conditions that every individual could live on the prairies of the west, out of doors, be provided with the best of food, most congenial of tasks, and free from overwork and worry. Needless to say, the figures in the table do not imply such Utopian conditions, nor do they imply new medical discoveries. . . . The hypothetical condition se-

* Irving Fisher, Bulletin 30, Report on National Vitality.

lected for the meaning of the term 'preventable' is contained in the following definition: a ratio of preventability is the fraction of all deaths which would be avoided if knowledge now existing among well-informed men in the medical profession were actually applied in a reasonable way and to a reasonable extent. The term 'reasonable' is of course elastic, and will be somewhat differently interpreted by different persons, but, as in law, where 'reasonable care' is often used as a proviso, it is impossible to make any more specific condition."

In regard to the collection and preparation of the information, we quote also: "The estimates of preventability . . . need special explanation. In a few cases, these estimates are based on statistical experience. The great majority of them are based on clinical experience merely, without any exact statistics. They are thus in the nature of expert guesses. The experts in all cases are physicians. . . . Those who gave to the construction of these estimates the benefit of their experience, observations and reading were especially asked above all to be conservative. In order to avoid any possibility of exaggeration of their estimates in the table their average was taken, and then the estimate entered as below the average given. When, as was true in a large proportion of cases, the different estimates agreed fairly well, the average was employed, or rather the nearest figure ending in 0, or 5 next below the average. If the individual estimates diverged widely, an estimate was used below the average, favoring the conservative estimates rather than the optimistic. Also in cases where only a few estimates were obtainable, the estimate as entered was put below the average of those given." Because of the conservative way in which the ratios were prepared we shall often find it convenient in the future to speak of the corresponding prevention of deaths as "reasonable" to distinguish it from another plan to be considered later.

The ratios of preventability are given in the following table.

TABLE I.*

SHOWING FISHER'S RATIOS OF PREVENTABILITY FOR THE DISEASES ENUMERATED IN THE MORTALITY STATISTICS OF THE UNITED STATES, TOGETHER WITH THE RELATIVE IMPORTANCE OF EACH DISEASE AS INDICATED BY THE PERCENTAGE THE NUMBER OF ITS DEATHS BEARS TO THE TOTAL NUMBER OF DEATHS.

	Causes of Death.	Prominence of Disease. Per Cent. of all Deaths.	Ratio of Preventability. Per Cent.
1	Premature birth	2.0	40
2	Congenital malformation of the heart	.55	0
3	Other congenital malformations	.3	0
4	Congenital debility	2.3	40
5	Hydrocephalus	.1	0
6	Venereal diseases	.3	70
7	Diarrhea and enteritis	7.74	60
8	Measles	.8	40
9	Acute bronchitis	1.1	30
10	Broncho-pneumonia	2.4	50
11	Whooping cough	.9	40
12	Croup	.3	75
13	Meningitis	1.6	70
14	Diseases of larynx—not laryngitis	.07	40
15	Laryngitis	.06	40
16	Diphtheria	1.4	70
17	Scarlet fever	.5	50
18	Diseases of lymphatics	.01	20
19	Tonsilitis	.05	45
20	Tetanus	.19	80
21	Tuberculosis—not of lungs	.17	75
22	Abscess	.08	60
23	Appendicitis	.7	50
24	Typhoid fever	2.0	85
25	Puerperal convulsions	.2	30
26	Puerperal septicemia	.4	85
27	Other diseases of childbirth	.36	50
28	Diseases of tubes	.1	65
29	Peritonitis	.5	55
30	Smallpox	.01	75
31	Tuberculosis of lungs	9.9	75
32	Violence	7.5	35
33	Malarial fever	.2	80
34	Septicemia	.3	40
35	Epilepsy	.29	0
36	General, ill-defined, and unknown causes (including "heart failure," "dropsy," and "convulsions")	9.2	30
37	Erysipelas	.3	60
38	Pneumonia (lobar and unqualified)	7.0	45
39	Acute nephritis	.6	30
40	Pleurisy	.27	55
41	Acute yellow atrophy of liver	.02	0
42	Obstructions of intestines	.6	25
43	Alcoholism	.4	85
44	Hemorrhage of lungs	.1	80
45	Diseases of the thyroid body	.02	10
46	Ovarian tumor	.07	0
47	Uterine tumor	.1	60
48	Rheumatism	.5	10
49	Gangrene of lungs	.03	0
50	Anemia, leukemia	.4	50
51	Chronic poisonings	.05	70
52	Congestion of lungs	.4	50
53	Ulcer of stomach	.2	50
54	Carbuncle	.03	50
55	Pericarditis	.1	10
56	Cancer of female congenital organs	.6	0
57	Dysentery	.5	80
58	Gastritis	.65	50
59	Cholera nostras	.09	50
60	Cirrhosis of liver	.9	60

*Fisher's Report, p. 104.

TABLE I—Continued.

	Cause of Death.	Prominence of Disease. Per Cent. of all Deaths.	Ratio of Preventability. Per Cent.
61	General paralysis of insane	.3	75
62	Hyatid tumors of liver	.002	75
63	Endocarditis	.8	25
64	Locomotor ataxia	.17	35
65	Diseases of veins	.04	40
66	Cancer of breast	.4	0
67	Diabetes	.8	10
68	Biliary calculi	.17	40
69	Hernia	.27	70
70	Cancer not specified	.9	0
71	Tumor	.08	0
72	Bright's disease	5.6	40
73	Embolism and thrombosis	.26	0
74	Cancer of intestines	.55	0
75	Cancer of stomach and liver	1.7	0
76	Calculi of urinary tract	.03	10
77	Cancer of mouth	.1	0
78	Heart disease	8.1	25
79	Influenza	.7	50
80	Asthma and emphysema	.23	30
81	Angina pectoris	.4	25
82	Apoplexy	4.4	35
83	Cancer of skin	.2	0
84	Chronic bronchitis	.8	30
85	Paralysis	1.0	50
86	Softening of brain	.2	0
87	Diseases of arteries	.83	10
88	Diseases of bladder	.2	45
89	Gangrene	.25	60
90	Old age	2.0	0

The area used as a basis of the investigation comprises the states Connecticut, Indiana, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and the District of Columbia. These states, together with several cities in other states formed, in the years 1900–5, what is known as the "registration area." The essential and distinctive characteristic of the registration area is that its annual registration of deaths is regarded officially as having an error of less than 10 per cent. Additions have been made to this area since 1905 but it was thought best to limit the area under observation to the 11 registration states enumerated above, as these states were the only registration states to continue as such throughout the period considered—the 11 years 1900–10.

The plans for the construction of the mortality tables are merely plans for the computation of the corresponding death rates for each age. Once the death rates are computed, the rest of the mortality table is set up very easily.

The data necessary for this computation comprise the deaths for each year of age and the population at the beginning of that year.

The deaths are given directly in the government mortality statistics, but the population data given in the census reports do not pertain to the population at the beginning any more than they do at the end of the year. We usually assume the population data to refer to the population at the middle of the year and that to determine the population at the beginning of the year the ordinary population data must be increased by the number of deaths (usually one half of the total number) that have occurred since the beginning of the year.

The quotient of the deaths by the population at the beginning of the year for each age gives the death rate required. More refined methods would be necessary to compute death rates at ages in the neighborhood of the age of birth if much emphasis were to be placed upon the direct discussion of the several mortality tables, but as we are concerned here only with differences in corresponding results of two such tables, such methods are regarded as unnecessary.

From now on we shall often refer to those whose deaths are prevented as "restored" or as "restorations;" we shall refer also to those diseases which have the ratio "zero" in Table I as "unpreventable" instead of using the longer expression "diseases whose deaths are unpreventable."

The computation of the death rates of Table I which is based upon actual deaths is straightforward and involves no particular difficulty.

The plan for computing the death rates based upon mortality conditions wherein preventable deaths are prevented requires special explanation. As a concrete illustration, let us assume 1,000,000 persons to be living in a given community all at exactly the same age and that 50,000 of that number die during the succeeding year. We say that the death rate for that age is .05000. Assuming also that 5,000 of the 50,000 deaths are due, say to pneumonia, what would be the death rate for that age if 60 per cent., or 3,000 of the deaths due to pneumonia were prevented? In other words, how many deaths would now occur among the 1,000,000? Evidently,

the number of deaths would be 50,000 minus 3,000 plus whatever deaths would occur among the 3,000 restored, due to other diseases than pneumonia. The only way to determine how many deaths would occur among the restored is to assume the restored to be normal persons again and hence subject to ordinary diseases just as normal persons, in which case it is necessary merely to multiply the 3,000 by the probability of dying from the effects of diseases other than pneumonia. This probability is identically the death rate based upon the total number of actual deaths (as given by the government mortality statistics) diminished by the number of deaths due to pneumonia.

The method of computing death rates wherein the deaths from a large number of diseases are prevented, is exactly analogous to the above case of a single disease. The number of deaths that will occur among the restored is ascertained by multiplying the number of restored by the probability of dying from the effects of unpreventable diseases. We obtain this probability for each age by entering Fisher's table of ratios and ascertaining just what diseases are unpreventable at all (have the ratio "zero") and then divide the total number of deaths due to these diseases by the corresponding population.

If we let q'_x represent this probability or death rate based upon deaths due to unpreventable diseases, and r_x the number of restorations, the death rate for any age x, when preventable deaths are prevented, becomes

$$q_x = \frac{d_x - r_x + q'_x r_x}{l_x} = \frac{d_x - (1 - q'_x) r_x}{l_x} \qquad \text{(a)}$$

which, for the numerical example given above, becomes

$$q_x = \frac{50{,}000 - 3{,}000 + q'_x \cdot 3{,}000}{1{,}000{,}000} = \frac{50{,}000 - (1 - q'_x)\, 3{,}000}{1{,}000{,}000}$$

We have used the death rates represented by q'_x also to construct a third mortality table (Table III) whose use and importance will be explained later.

After the three sets of death rates werecomputed, the three mortality tables themselves were constructed in accordance with the definition of such a table, given previously.

The data used in this investigation comprise the deaths and population by ages for the area considered. In other words, the data comprise the essential material for computing the death rates for the different ages.

The population for 1900 of the 11 registration states enumerated above is given for each age, but, as is well known there is a great concentration at ages which are a multiple of 5, particularly those ending in 0; so the data were first combined into quinquennial age groups and then the values for each age were interpolated. The population data for 1910 were available only in quinquennial age groups.

The different processes of interpolation used are described in the section devoted to the mathematical computation of the death rates.

The population data for the years 1900 and 1910 by quinquennial age groups are as follows:

TABLE II.

POPULATION BY AGE GROUPS FOR YEARS 1900 AND 1910 FOR ELEVEN REGISTRATION STATES.

Ages.	1900.	1910.	Ages.	1900.	1910.
0	437,944	508,615	40–44	1,247,880	1,563,163
0–4	2,072,797	2,407,441	45–49	1,013,403	1,324,060
5–9	1,984,846	2,192,715	50–54	872,741	1,133,970
10–14	1,819,115	2,112,774	55–59	685,469	821,327
15–19	1,804,950	2,216,868	60–64	562,777	672,483
20–24	1,905,779	2,354,725	65–74	702,679	864,675
25–29	1,839,826	2,203,961	75–84	263,124	314,937
30–34	1,630,050	1,948,886	85–94	30,547	50,504
35–39	1,474,697	1,831,043	95–	1,919	2,163

The deaths are given for the age groups 0, 1, 2, 3, 4, 5–9, 10–19, 20–29,—"90 and above," and are given by single and total years from 1900 to 1910 inclusive as follows:

TABLE III.

DEATHS BY AGE GROUPS FOR EACH YEAR OF 1900-1910 AND THE TOTAL, FOR ELEVEN REGISTRATION STATES.

Years.	0.	1.	2.	3.	4.	5-9.	10-19.	20-29.
1900	71,117	16,866	7,439	4,691	3,416	9,242	14,169	27,546
1901	62,759	14,389	6,333	4,136	3,159	8,535	13,354	26,853
1902	62,634	14,367	6,523	3,912	2,954	8,121	12,570	25,198
1903	60,751	13,422	6,115	3,936	2,747	8,422	13,325	25,686
1904	64,805	14,213	6,242	4,030	2,982	8,712	15,009	27,198
1905	66,894	13,806	6,073	3,757	2,660	8,197	14,174	26,387
1906	70,750	15,416	6,513	3,990	2,816	7,938	13,860	26,188
1907	68,962	14,114	6,057	3,891	2,755	7,788	14,002	26,576
1908	68,881	14,003	6,093	3,821	2,653	7,546	13,144	24,958
1909	67,681	14,870	6,208	3,717	2,679	7,412	12,752	24,214
1910	72,096	15,041	6,643	4,084	2,785	7,972	13,320	25,874
Total	730,330	160,557	70,230	43,875	31,606	89,885	149,679	286,678

Years.	30-39.	40-49.	50-59.	60-69.	70-79.	80-89.	90- .
1900	28,322	27,152	30,987	37,556	38,631	21,471	3,424
1901	28,378	28,042	31,737	38,755	38,958	22,001	3,490
1902	27,075	26,707	30,236	36,789	37,030	20,147	3,247
1903	27,833	27,858	31,893	39,197	39,468	21,746	3,530
1904	29,935	29,773	33,939	42,050	42,515	23,471	3,775
1905	29,209	29,959	33,356	42,060	42,025	23,009	3,619
1906	29,923	30,639	34,173	42,485	41,712	23,286	3,633
1907	31,343	32,569	36,637	45,983	45,751	25,727	3,950
1908	28,684	30,705	35,151	43,530	43,662	24,124	3,878
1909	28,768	31,126	35,396	45,249	45,183	24,148	3,875
1910	30,014	33,211	38,539	48,067	48,672	26,178	4,223
Total	319,384	327,741	372,044	461,721	463,607	255,306	40,646

After the total deaths for each of the 145 diseases listed in the mortality statistics (by age groups) for all the area considered, and the 11 years 1900–10 were determined, these totals were multiplied by the appropriate ratios of preventability given by Professor Fisher, to obtain the number of deaths that are preventable. The following table gives the total number of preventable deaths:

TABLE IV.

TOTAL NUMBER OF PREVENTABLE DEATHS FOR THE NUMBER OF YEARS AND AREA GIVEN.

Ages.	rx.	Ages.	rx.
0	312,742	30-39	163,897
1	83,175	40-49	144,721
2	41,467	50-59	138,239
3	23,438	60-69	159,062
4	17,041	70-79	162,301
5-9	46,658	80-89	73,501
10-19	79,350	90-	9,320
20-29	160,177		

The following table gives the total number of deaths due only to unpreventable diseases (those that have the ratio "zero" in Table I:

TABLE V.

DEATHS DUE TO DISEASES REGARDED AS ABSOLUTELY UNPREVENTABLE.

Ages.	Deaths.	Ages.	Deaths.
0	32,748	30–39	15,109
1	1,396	40–49	32,111
2	702	50–59	46,415
3	411	60–69	56,755
4	339	70–79	63,779
5–9	1,071	80–89	58,794
10–19	2,902	90–	16,845
20–29	6,311		

After the populations for 1900 and 1910, as given in Table II, were averaged, and this average multiplied by the number 11 (as explained later), the final data, also the totals of Table III and the data of Tables IV and V were expressed in quinquennial age groups (as explained later), as follows:

Age.	Table II.	Age.	Table III.	Table IV.	Table V.
0	5,206,075	0	730,330	312,742	32,748
0–4	24,641,309	1	160,557	83,175	1,396
5–9	22,976,586	2	70,230	41,467	702
10–14	21,625,390	3	43,875	23,438	411
15–19	22,119,999	4	31,606	17,041	339
20–24	23,432,772	5–9	89,885	46,658	1,071
25–29	22,240,829	10–14	51,197	24,753	1,356
30–34	19,684,148	15–19	98,482	54,597	1,546
35–39	18,181,570	20–24	132,733	74,805	2,386
40–44	15,460,737	25–29	153,945	85,372	3,925
45–49	12,856,047	30–34	157,125	82,914	5,942
50–54	11,036,911	35–39	162,259	80,983	9,167
55–59	8,287,378	40–44	160,579	73,965	14,098
60–64	6,793,930	45–49	167,162	70,756	18,013
65–69	5,162,683	50–54	177,648	68,224	21,668
70–74	3,457,764	55–59	194,396	70,015	24,747
75–79	2,097,494	60–64	225,175	78,064	27,292
80–84	1,081,842	65–69	236,546	80,998	29,463
85–89	410,827	70–74	244,698	86,492	31,762
90–94	84,454	75–79	218,909	75,809	32,017
95–	22,451	80–84	166,834	53,610	30,772
		85–89	88,472	19,891	28,022
		90–	40,646	9,320	16,845

We shall now show more in detail the methods used in computing the three sets of death rates for mortality Tables 1, 2, and 3.

In all three cases we averaged the data for the 11 years in order to obtain results based upon an average year. However,

this plan of averaging the data was carried out by assuming as our average year that one whose population and whose deaths were equal in number to the corresponding totals of the 11 years.

Since the population data are issued only once in 10 years, we assumed that the population increased in arithmetical progression from the year 1900 to the year 1910. That is, we averaged the populations for 1900 and 1910, and multiplied the average by 11 to obtain the population for the 11 years. Perhaps a more satisfactory plan would be to assume that the population increased in geometrical progression, but as we are not concerned with values given directly in the mortality tables but rather with differences of such values, the extra work required to carry through such a plan was considered unnecessary.

From the data given by age groups in Tables II, III, IV, and V, the population, deaths, and restorations for each age were obtained by methods of interpolation to be explained later; then the populations at the beginning of the year for each age were found in accordance with the explanation given above.

The death rates of Table 1, which is based upon actual deaths, were then found by dividing the number of deaths (given in Table III) by the population at the beginning of the year (obtained from the data of Table II), for each age.

The death rates of Table 3 which is based upon deaths due only to unpreventable diseases, were found by dividing the number of deaths due only to unpreventable diseases (given in Table V) by the same population which was used to compute the death rates of Table 1.

The death rates of Table 2 which is based upon deaths that would occur if unnecessary deaths were prevented, were found through the use of the formula

$$q_x = \frac{d_x - (1 - q_x')r_x}{l_x} \qquad \text{(a)}$$

given above, where d_x refers to the deaths of Table III, q_x the death rates of Table 3, r_x the restorations of Table IV

and l_x the populations which were used to compute the death rates of Tables 1 and 2, for the different ages.

TABLE 1.

MORTALITY TABLE BASED UPON THE ACTUAL DEATHS OF ELEVEN REGISTRATION STATES FOR THE YEARS 1900-1910.

Age.	l_x.	d_x.	q_x.	$\mathring{e}_x$.	Age.	l_x.	d_x.	q_x.	$\mathring{e}_x$.
0..........	125,325	16,831	.134300	49.44	55..........	68,399	1,350	.019739	17.74
1..........	108,494	3,431	31622	56.03	56..........	67,049	1,443	21527	17.08
2..........	105,063	1,488	14165	56.84	57..........	65,606	1,538	23436	16.45
3..........	103,575	933	9001	56.64	58..........	64,068	1,617	25241	15.83
4..........	102,642	676	6585	56.15	59..........	62,451	1,682	26929	15.23
5..........	101,966	543	.005327	55.51	60..........	60,769	1,746	.028729	14.63
6..........	101,423	454	4481	54.81	61..........	59,023	1,807	30610	14.05
7..........	100,969	380	3757	54.06	62..........	57,216	1,864	32575	13.48
8..........	100,589	318	3164	53.26	63..........	55,352	1,923	34749	12.92
9..........	100,271	271	2706	52.43	64..........	53,429	1,987	37193	12.36
10..........	100,000	241	.002407	51.57	65..........	51,442	2,047	.039790	11.82
11..........	99,759	223	2244	50.69	66..........	49,395	2,102	42556	11.29
12..........	99,536	224	2246	49.80	67..........	47,293	2,161	45688	10.79
13..........	99,312	233	2342	48.91	68..........	45,132	2,222	49240	10.26
14..........	99,079	258	2605	48.03	69..........	42,910	2,281	53151	9.77
15..........	98,821	342	.003459	47.15	70..........	40,629	2,330	.057337	9.29
16..........	98,479	404	4098	46.31	71..........	38,299	2,339	61074	8.82
17..........	98,075	453	4616	45.50	72..........	35,960	2,397	66668	8.36
18..........	97,622	478	4900	44.71	73..........	33,563	2,415	71941	7.93
19..........	97,144	490	5039	43.93	74..........	31,148	2,424	77817	7.50
20..........	96,654	505	.005222	43.15	75..........	28,724	2,425	.084409	7.09
21..........	96,149	520	5406	42.37	76..........	26,299	2,418	91945	6.70
22..........	95,629	536	5608	41.60	77..........	23,881	2,391	10010	6.31
23..........	95,093	557	5860	40.83	78..........	21,490	2,330	10844	5.98
24..........	94,536	581	6144	40.07	79..........	19,160	2,241	11693	5.64
25..........	93,955	603	.006415	39.31	80..........	16,919	2,138	.12638	5.32
26..........	93,352	624	6685	38.56	81..........	14,781	2,021	13675	5.02
27..........	92,728	643	6935	37.82	82..........	12,760	1,888	14796	4.74
28..........	92,085	659	7152	37.08	83..........	10,872	1,741	16009	4.47
29..........	91,426	672	7347	36.34	84..........	9,131	1,580	17302	4.23
30..........	90,754	686	.007554	35.61	85..........	7,551	1,364	.18067	4.01
31..........	90,068	700	7772	34.88	86..........	6,187	1,201	19413	3.79
32..........	89,368	713	7980	34.15	87..........	4,986	1,037	20792	3.58
33..........	88,655	724	8165	33.42	88..........	3,949	879	22262	3.39
34..........	87,931	733	8331	32.69	89..........	3,070	728	23699	3.22
35..........	87,198	741	.008501	31.96	90..........	2,342	578	.24684	3.06
36..........	86,457	750	8672	31.23	91..........	1,764	461	26134	2.90
37..........	85,707	759	8861	30.50	92..........	1,303	360	27619	2.75
38..........	84,948	772	9086	29.77	93..........	943	276	29138	2.61
39..........	84,176	787	9350	29.03	94..........	668	205	30686	2.48
40..........	83,389	803	.009631	28.30	95..........	463	149	.32260	2.36
41..........	82,586	820	9930	27.57	96..........	314	106	33856	2.24
42..........	81,766	841	10288	26.85	97..........	208	74	35470	2.12
43..........	80,925	868	10727	26.12	98..........	134	50	37097	2.02
44..........	80,057	899	11232	25.40	99..........	84	33	38731	1.92
45..........	79,158	930	.011748	24.68	100..........	51	21	.40369	1.83
46..........	78,228	972	12421	23.97	101..........	30	13	42003	1.77
47..........	77,256	1,007	13034	23.26	102..........	17	7	43630	1.74
48..........	76,249	1,033	13543	22.56	103..........	10	5	45243	1.60
49..........	75,216	1,053	13995	21.87	104..........	5	2	46839	1.70
50..........	74,163	1,075	.014501	21.17	105..........	3	1	.48409	1.40
51..........	73,088	1,098	15020	20.47	106..........	2	1	49949	1.00
52..........	71,990	1,134	15745	19.78	107..........	1	1	51452	.50
53..........	70,856	1,190	16792	19.09	108..........	0			
54..........	69,666	1,267	18191	18.40					

We shall now explain the methods of interpolation. As all the deaths are available in the age groups 0, 1, 2, 3, 4, 5–9,

10–19, 20–29,—"90 and above," and the population in the age groups 0, 0–4, 5–9, 10–14,—60–64, 65–74,—85–94, "95 and above," columns of T_x were formed in each case by successive additions of the numbers at the different ages, such that, T_x represents the total number at ages x and above. For example, in the case of the deaths, T_{40} means the total number of deaths at ages 40 and above. This change into columns of T_x is seen to be necessary from the character of the original data.

Ordinary fifth differences were used to interpolate single values to form quinquennial age groups out of the decennial age groups.

The four values of T_x within each quinquennial age group (except, of course, the two at each end) were interpolated by what is known as Sprague's osculatory method. This method is so well explained in so many places that we deem it sufficient to state merely that its use has the advantage over ordinary differences in that not only the slope but also the curvature of the curve (representing the values considered) at the points of intersection of the different partial interpolation curves is considered. As a result, the curve representing the completed series of values becomes much less undulating in form and hence more smooth throughout.

The final leading differences for interpolating four values between u_2 and u_3 of the series of equidistant values u_0, u_1, u_2, u_3, u_4, and u_5 are as follows:

$$
\begin{array}{lccccc}
(1) & \dfrac{\Delta u_0}{5} & + 8\dfrac{\Delta^2 u_0}{5^2} & + 11\dfrac{\Delta^3 u_0}{5^3} & - 11\dfrac{\Delta^4 u_0}{5^4} & + \dfrac{\Delta^5 u_0}{5^4} \\[2ex]
(2) & & 1\ \text{"} & + 6\ \text{"} & + 1\ \text{"} & + 3\ \text{"} \\[1ex]
(3) & & & 1\ \text{"} & + 4\ \text{"} & - 3\ \text{"} \\[1ex]
(4) & & & & 1\ \text{"} & - 2\ \text{"} \\[1ex]
(5) & & & & & 5\ \text{"}
\end{array}
$$

TABLE 2.

MORTALITY TABLE SHOWING THE DEATH RATES AND EXPECTATIONS OF LIFE ASSUMING DEATHS TO BE PREVENTED ACCORDING TO THE RATIOS GIVEN IN TABLE I.

Age.	l_x.	d_x.	q_x.	$\mathring{e}_x$.	Age.	l_x.	d_x.	q_x.	$\mathring{e}_x$
0..........	112,537	8,686	.077188	62.11	57..........	81,845	1,028	.012493	21.46
1..........	103,851	1,583	15246	66.26	56..........	80,822	1,108	13714	20.72
2..........	102,268	594	5022	66.28	57..........	79,714	1,197	15020	20.00
3..........	101,674	426	4193	65.67	58..........	78,517	1,278	16272	19.30
4..........	101,248	307	3035	64.94	59..........	77,239	1,348	17453	18.61
5..........	100,941	249	.002459	64.13	60..........	75,891	1,419	.018698	17.93
6..........	100,692	213	2115	63.27	61..........	74,472	1,489	19988	17.27
7..........	100,479	182	1819	62.42	62..........	72,983	1,557	21332	16.61
8..........	100,297	158	1575	61.54	63..........	71,426	1,630	22821	15.96
9..........	100,139	139	1385	60.63	64..........	69,796	1,709	24487	15.32
10..........	100,000	126	.001259	59.72	65..........	68,087	1,788	.026255	14.69
11..........	99,874	118	1186	58.79	64..........	66,299	1,866	28148	14.07
12..........	99,756	116	1167	57.86	67..........	64,433	1,947	30222	13.47
13..........	99,640	120	1202	56.80	68..........	62,486	2,028	32462	12.87
14..........	99,520	129	1292	56.00	69..........	60,458	2,107	34855	12.29
15..........	99,391	160	.001610	55.07	70..........	58,351	2,184	.037423	11.71
16..........	99,231	183	1849	54.16	71..........	56,167	2,228	39669	11.15
17..........	99,048	202	2043	53.26	72..........	53,939	2,330	43189	10.59
18..........	98,846	213	2151	52.36	73..........	51,609	2,407	46645	10.04
19..........	98,633	217	2205	51.48	74..........	49,202	2,491	50628	9.51
20..........	98,416	224	.002279	50.59	75..........	46,711	2,574	.055109	8.99
21..........	98,192	231	2356	49.70	76..........	44,137	2,661	60294	8.49
22..........	97,961	240	2445	48.82	77..........	41,476	2,737	65981	8.00
23..........	97,721	250	2558	47.94	78..........	38,739	2.784	71872	7.53
24..........	97,471	262	2689	47.06	79..........	35,955	2,805	78005	7.07
25..........	97,209	274	.002817	46.18	80..........	33,150	2,818	.084998	6.63
26..........	96,935	286	2949	45.31	81..........	30,332	2,818	92901	6.20
27..........	96,649	298	3080	44.45	82..........	27,514	2,801	10179	5.78
28..........	96,351	309	3208	43.58	83..........	24,713	2,764	11184	5.38
29..........	96,042	321	3337	42.72	84..........	21,949	2,706	12328	4.99
30..........	95,721	333	.003476	41.86	85..........	19,243	2,538	.13192	4.62
31..........	95,388	346	3628	41.01	86..........	16,705	2,447	14650	4.25
32..........	95,042	359	3776	40.15	87..........	14,258	2,342	16427	3.89
33..........	94,683	370	3907	39.30	88..........	11,916	2,239	18792	3.56
34..........	94,313	380	4027	38.46	89..........	9,677	2,152	22235	3.27
35..........	93,933	390	.004154	37.61	90..........	7,525	1,858	.24684	3.06
36..........	93,543	401	4286	36.76	91..........	5,667	1,481	26134	2.90
37..........	93,142	413	4433	35.92	92..........	4,186	1,156	27619	2.75
38..........	92,729	427	4610	35.08	93..........	3,030	883	29138	2.61
39..........	92,302	445	4818	34.24	94..........	2,147	659	30686	2.48
40..........	91,857	460	.005007	33.40	95..........	1,488	480	.32260	2.36
41..........	91,397	482	5277	32.57	96..........	1,008	341	33856	2.24
42..........	90,915	507	5574	31.74	97..........	667	237	35470	2.13
43..........	90,408	533	5897	30.91	98..........	430	160	37097	2.03
44..........	89,875	561	6247	30.09	99..........	270	105	38731	1.94
45..........	89,314	592	.006633	29.28	100..........	165	67	.40369	1.86
46..........	88,722	627	7068	28.47	101..........	98	41	42003	1.79
47..........	88,095	661	7507	27.67	102..........	57	25	43630	1.71
48..........	87,434	692	7914	26.87	103..........	32	14	45243	1.66
49..........	86,742	721	8308	26.09	104..........	18	8	46839	1.56
50..........	86,021	751	.008734	25.30	105..........	10	5	.48409	1.40
51..........	85,271	782	9171	24.52	106..........	5	2	.49949	1.30
52..........	84.489	822	9728	23.74	107..........	3	2	51452	.83
53..........	83,667	876	10471	22.97	108..........	1	1	52912	.50
54..........	82,791	946	11431	22.21	109..........	0			

To apply this method of interpolation, the observed values of T_x are differenced, the differences divided by the appropriate power of 5 (or multiplied by the corresponding decimal)

as indicated above, and then the leading differences themselves formed in accordance with the above scheme.

The interpolated values of T_x for each interval are formed by the continued addition of the differences in the usual way, and there is a good check on the computation because the next higher quinquennial value of T_x given in the original or observed data must be reproduced at each stage.

Each quinquennial interval will have its own set of differences derived from the differences of an age ten years younger, but the easiest plan is to compute the successive fifth differences which by a continued addition to the lower differences of the preceding sub-interval (in each case) will lead to the desired interpolated values of the next interval. This plan avoids the separate computation of the leading differences for each interval to be interpolated.

The scheme of computing successive fifth differences has been suggested before but we were unable to find anywhere the formulas for computing these fifth differences, so we have derived them ourselves to be as follows:

$$4\,\Delta^5 + \Delta^6,\ -6\Delta^5,\ -6\,\Delta^5 - 6\Delta^6,\ 4\,\Delta^5 + 3\,\Delta^6,\ 5\,\Delta^5 + 5\Delta^6,$$

$$\text{where } \Delta^n = \frac{\Delta^n u_0.}{5^4}$$

After the interpolation itself is completed the subtraction of each value of T_x from the one at the age next below will give the desired column (of deaths or population) of values for each age.

As Sprague's method of interpolation requires two quinquennial periods on each side of the interval into which five sub-intervals are to be introduced, the interpolation at the ends of each set of data were performed by using ordinary third differences. For the inner of the two quinquennial periods at the ends of each set of data the interpolations were applied centrally. Thus the ordinates of the curve through the points u_0, u_1, u_2, and u_3 or

$$u_x = u_0 + x\Delta u_0 + \frac{x\,(x-1)}{2\,!}\,\Delta^2 u_0 + \frac{x\,(x-1)\,(x-2)}{3\,!}\,\Delta^3 u_0$$

for $x = 5/5$, $6/5$—$10/5$ were differenced five times to form the

leading differences to interpolate four values between u_1 and u_2. The leading differences are as follows:

(1)	$\frac{\Delta u_0}{5}$	$+ 3 \frac{\Delta^2 u_0}{5^2}$	$- 4 \frac{\Delta^3 u_0}{5^3}$
(2)		1 "	+ 1 "
(3)			1 "
(4 and 5)			0

The ordinates of the same curve for $x = 0/5—1/5,\ 5/5$ were differenced five times also to form the leading differences for interpolating four intermediate values in the outer quinquennial periods. Thus, these interpolations are not applied centrally. The leading differences are as follows:

(1)	$\frac{\Delta u_0}{5}$	$- 2 \frac{\Delta^2 u_0}{5^2}$	$+ 6 \frac{\Delta^3 u_0}{5^3}$
(2)		1 "	− 4 "
(3)			1 "
(4 and 5)			0

The main advantage in using the above tables of leading differences, besides convenience and system, is the accompanying check upon the accuracy of the computation, just as in the application of Sprague's method.

A very little investigation will reveal the fact that the part of the mortality table at and beyond age 90 is very flexible as far as the data are concerned, but that the difference in the expectation of life at birth on two plans, even though they differ widely, is insignificant, because at the ulterior end of the table we are dealing not only with very small populations in comparison with the radix (or population at the beginning of the table), but also with the difference of two such small populations.

This fact is very important, for we tested, in various ways the possibility of lengthening the mortality tables, and concluded in every case that any significant lengthening of the table would require quite unreasonable assumptions. For

example, an assumption that the death rate shall remain constantly equal to that of age 89 after that age, lengthens the table itself scarcely a year and has no significant effect upon the expectation of life. We wish to emphasize this fact in order to make it clear that we have no choice worth while in dealing with the ulterior end of the mortality table.

TABLE 3.

MORTALITY TABLE SHOWING MORTALITY CONDITIONS UNDER THE MORE EXTREME OF ASSUMPTIONS CONSIDERED IN THIS PAPER IN REGARD TO THE PREVENTION OF DEATHS.

Age.	lx.	dx.	qx.	$\overset{\circ}{e}_x$.	Age.	lx.	dx.	qx.	$\overset{\circ}{e}_x$.
0	100,778	696	.006908	84.89	55	97,260	248	.002553	31.69
1	100,082	29	284	84.49	56	97,012	273	2819	30.77
2	100,053	14	144	83.51	57	96,739	298	3079	29.86
3	100,039	8	85	82.52	58	96,441	319	3307	28.95
4	100,031	8	71	81.53	59	96,122	332	3451	28.04
5	100,023	4	.000040	80.53	60	95,790	348	.003630	27.14
6	100,019	4	43	79.53	61	95,442	364	3811	26.23
7	100,015	4	47	78.54	62	95,078	383	4027	25.33
8	100,011	6	51	77.54	63	94,695	409	4314	24.43
9	100,005	5	54	76.54	64	94,286	440	4670	23.54
10	100,000	6	.000058	75.55	65	93,846	474	.005052	22.65
11	99,994	6	61	74.55	66	93,372	511	5472	21.76
12	99,988	6	64	73.56	67	92,861	552	5943	20.88
13	99,982	7	66	72.56	68	92,309	596	6457	20.00
14	99,975	7	67	71.57	69	91,713	644	7017	19.12
15	99,968	6	.000065	70.57	70	91,069	696	.007646	18.25
16	99,962	7	66	69.58	71	90,373	744	8235	17.39
17	99,955	7	68	68.58	72	89,629	819	9139	16.53
18	99,948	7	72	67.59	73	88,810	895	11080	15.68
19	99,941	8	78	66.59	74	87,915	985	11207	14.83
20	99,933	8	.000084	65.60	75	86,930	1,089	.012528	14.00
21	99,925	9	91	64.60	76	85,841	1,214	14143	13.17
22	99,916	10	100	63.61	77	84,627	1,352	15973	12.35
23	99,906	11	111	62.61	78	83,275	1,502	18038	11.54
24	99,895	12	125	61.62	79	81,773	1,666	20370	10.74
25	99,883	14	.000140	60.63	80	80,107	1,859	.023208	9.96
26	99,869	16	158	59.63	81	78,248	2,087	26666	9.18
27	99,853	18	177	58.64	82	76,161	2,354	30906	8.42
28	99,835	20	196	57.66	83	73,807	2,671	36194	7.67
29	99,815	22	217	56.67	84	71,136	3,050	42877	6.94
30	99,793	24	.000242	55.68	85	68,086	3,379	.049624	6.23
31	99,769	27	272	54.69	86	64,707	3,923	60632	5.53
32	99,742	30	303	53.71	87	60,784	4,625	76085	4.86
33	99,712	33	336	52.72	88	56,159	5,600	99715	4.21
34	99,679	37	369	51.74	89	50,559	7,061	13966	3.62
35	99,642	40	.000406	50.76	90	43,498	9.573	.22008	3.15
36	99,602	44	443	49.78	91	33,925	8,866	26134	2.90
37	99,558	49	492	48.80	92	25,059	6,921	27619	2.75
38	99,509	56	560	47.82	93	18,138	5,285	29138	2.61
39	99,453	64	643	46.85	94	12,853	3,944	30686	2.48
40	99,389	73	.000732	45.88	95	8,909	2,874	.32260	2.36
41	99,316	82	830	44.92	96	6,035	2,043	33856	2.24
42	99,234	92	927	43.95	97	3,992	1,416	35470	2.14
43	99,142	101	1018	42.99	98	2,576	956	37097	2.04
44	99,041	110	1106	42.04	99	1,620	627	38731	1.94
45	98,931	119	.001204	41.08	100	993	401	.40369	1.85
46	98,812	129	1310	40.13	101	592	249	42003	1.77
47	98,683	140	1419	39.18	102	343	150	43630	1.70
48	98,543	150	1522	38.24	103	193	87	45243	1.62
49	98,393	160	1622	37.29	104	106	50	46839	1.55
50	98,233	169	.001725	36.36	105	56	27	.48409	1.48
51	98,069	179	1826	35.42	106	29	14	49949	1.40
52	97,885	191	1949	34.48	107	15	8	51452	1.23
53	97,694	207	2116	33.55	108	7	4	52912	1.07
54	97,487	227	2324	32.62	109	3	2		.83
					110	1	1		.50

The tables were completed, however, for the purpose of computing the expectations of life at the earlier ages.

The death rates for Tables 2 and 3 are, of course, less than the corresponding rates for Table 1 below age 90, but the curves representing the rates for Tables 2 and 3 are much steeper at the higher ages than that of Table 1; hence, any effort to interpolate in the two tables beyond age 90 results in death rates greater instead of less than those found in the same way for Table 1, a result which, of course, is not tenable.

As the best estimate of the death rates at the extreme ages, we assumed the same values in Tables 2 and 3 as in Table 1. Any systematic effort to obtain values less than those thus chosen resulted in absurd values. For example, the assumption of a longer mortality table for Tables 2 and 3 than for Table 1 leads to intermediate values of the death rates in the neighborhood of age 90 and beyond, in excess of unity.

The tables of deaths and restorations afford abundant material for profitable discussion and therefore merit careful and intelligent interpretation. Most of such discussion, however important and valuable, would prove only distantly related to the purpose of this paper, and so must be passed over for the present. We shall enumerate a few of the most important facts which are closely related to the subject under consideration.

(a) A careful comparison of the number of deaths given in Table III* for each year shows that although mortality conditions on the whole are gradually improving from year to year, they are improving only because the decrease in the death rates at the ages preceding age 40, except at the age of birth, exceeds the increase at ages beyond age 40. In other words, while diseases operative at the younger ages are show-

*It should be kept in mind that the population increased about 20 per cent. from year 1900 to year 1910.

ing wonderful improvement, those operative at the more advanced ages are actually growing more destructive.

(b) Comparison of the number of restorations in Table IV with the total number of deaths of Table III indicates that most of the preventable diseases are operative principally at the earlier ages. In fact, many diseases were found, in connection with the preparation of Table IV, which showed improvement at the earlier ages and a deterioration at the more advanced ages. It is apparent that most attention has been paid by scientists to the ills and weaknesses of youth rather than those of the older ages.

(c) If we assume the ratios of preventable deaths to all deaths by ages, as indicated by Tables III and IV covering the area composed of the 11 registration states considered in this paper, to hold for the whole of the United States, we find that about 6,000,000 deaths out of a total of 14,000,000 deaths that occurred in the United States during the eleven years 1900–10, were wholly unnecessary.

It has been noted that relatively few deaths at the older ages are preventable; we believe, however, that if scientists could be made to realize fully the importance of improving mortality conditions at the higher ages, just as great an improvement is possible at these ages as is exhibited at present at the younger ages.

It is difficult to imagine what a tremendous advance would be made if death rates at the older ages could be made to decrease instead of being allowed to increase. In other words, if in estimating the annual change in mortality conditions, we were allowed to register an improvement at the older ages and hence add a measure of this improvement to the measure of improvement at the younger ages, instead of allowing the effects of an improvement at the younger ages to be canceled to a large extent by the effects of a deterioration at the older ages, the results would be marvelous.

We are compelled to deal, in this paper, wholly with losses due to preventable deaths that can be expressed statistically; perhaps the greatest loss of all is one which we have no way of measuring numerically, and that is the wealth of experience, knowledge, and general wisdom of older persons much

the greater part of which is lost at the present time through premature loss of memory, intellectual and physical weakness, and all other characteristics of premature old age.

Some of the greatest authorities on the diseases of mankind believe the *average* length of life should be from 75 to 200 years. If such should be the length of life, it is evident that much must be done that has not, as yet, even been attempted, and the present discussion should make it clear at what point the main attack should be directed—at the diseases of the older ages.

We have already stated that a mortality table expresses concisely and clearly the mortality conditions based upon circumstances wherein the corresponding death rates are known and are used to construct the given mortality table. We shall now compare the mortality tables, (a) Table 1, which is based upon deaths as they occur at present, and (b) Table 2, in which preventable deaths are assumed to have been prevented, to ascertain the vital losses that are due to the occurrence of preventable deaths.

We have brought together the death rates of Tables 1 and 2, in Table 4 for purposes of readier comparison. We have also added a column of corresponding differences of these death rates, and a column of the percentages of these differences of the death rates based on actual deaths.

If we keep in mind that the general death rate for this country is about 14 per 1,000, this fact will help us to understand more completely a discussion of the two sets of death rates.

The excess in death rates, given in Table 4, due to the occurrence of preventable deaths begins at the maximum value of 57 per 1,000 and decreases very abruptly by ages to about 3 per 1,000 at age 1 and then on to the minimum value of 1 per 1,000 at age 10; the excess then increases about 5 or 6 per 10,000 each 5 years until at age 50 the excess has accumulated to about 6 per 1,000, or almost one half the general death rate. After age 50, the excess in the death rate about doubles itself every 5 years to the end of the table.

The percentage of this excess of the existing death rate starts in at zero at the highest ages and increases gradually, as age decreases, through 30 per cent. at age 80, 35 per cent.

at age 65, 40 per cent. at age 50, to over 50 per cent. from age 35 down to age 15, being a little over 56 per cent. between ages 20 and 25. For all ages below age 15, the percentage adheres closely to 50 per cent.

TABLE 4.

COMPARISON OF THE DEATH RATES UNDER THE TWO ASSUMPTIONS THAT DEATHS ARE AND ARE NOT PREVENTED ACCORDING TO THE RATIOS GIVEN IN TABLE I.

Age.	Deaths.			Per Cent.	Age.	Deaths.			Per Cent.
	Prevented.	Not Prevented.	Difference.			Prevented.	Not Prevented.	Difference.	
(1)	(2)	(3)	(4)	(4)÷(3)	(1)	(2)	(3)	(4)	(4)÷(3)
0	.077188	.134300	.057112	.426	45	.006633	.011748	.005115	.437
1	15246	31622	16376	518	46	7068	12421	5353	432
2	5022	14165	9143	644	47	7507	13034	5527	422
3	4193	9001	4808	533	48	7914	13543	5629	417
4	3035	6585	3550	539	49	8308	13995	5687	409
5	.002459	.005327	.002868	.538	50	.008734	.014501	.005767	.398
6	2115	4481	2366	528	51	9171	15020	5849	387
7	1819	3757	1938	515	52	9728	15745	6017	383
8	1575	3164	1589	503	53	10471	16792	6321	376
9	1385	2706	1321	487	54	11431	18191	6760	371
10	.001259	.002407	.001148	.476	55	.012493	.019739	.007246	.368
11	1186	2244	1058	472	56	13714	21527	7813	363
12	1167	2246	1079	480	57	15020	23436	8416	360
13	1202	2342	1140	471	58	16272	25241	8969	356
14	1292	2605	1313	503	59	17453	26929	9476	352
15	.001610	.003459	.001849	.534	60	.018698	.028729	.010031	.350
16	1849	4098	2249	550	61	19988	30610	10622	347
17	2043	4616	2573	557	62	21332	32575	11243	345
18	2151	4900	2749	562	63	22821	34749	11928	344
19	2205	5039	2834	562	64	24487	37193	12706	342
20	.002279	.005222	.002943	.564	65	.026255	.039790	.013535	.340
21	2356	5406	3050	564	66	28148	42556	14408	338
22	2445	5608	3163	564	67	30222	45688	15466	338
23	2558	5860	3302	563	68	32462	49240	16778	341
24	2689	6144	3455	563	69	34855	53151	18296	344
25	.002817	.006415	.003598	.560	70	.037423	.057337	.019914	.347
26	2949	6685	3736	558	71	39669	61074	21405	350
27	3080	6935	3855	556	72	43189	66668	23479	352
28	3208	7152	3944	552	73	46645	71941	25296	352
29	3337	7347	4010	546	74	50628	77817	27189	350
30	.003476	.007554	.004078	.540	75	.055109	.084409	.029300	.347
31	3628	7772	4144	533	76	60294	91945	31651	344
32	3776	7980	4204	527	77	65981	10010	34119	341
33	3907	8165	4258	521	78	71872	10844	36568	339
34	4027	8331	4304	517	79	78005	11693	38925	333
35	.004154	.008501	.004347	.511	80	.084998	.12638	.041382	.328
36	4286	8672	4386	506	81	92901	13675	43849	320
37	4433	8861	4428	500	82	10179	14796	4617	312
38	4610	9086	4476	492	83	11184	16009	4825	300
39	4818	9350	4532	485	84	12328	1730	4974	287
40	005007	.009631	.004624	.480	85	.13192	.180627	.04875	.269
41	5277	9930	4653	469	86	14650	19413	4763	246
42	5574	10288	4714	458	87	16427	20792	4365	210
43	5897	10727	4830	447	88	18792	22262	3470	156
44	6247	11232	4985	445	89	22235	23699	1464	62
					90	.24684	.24684	.000000	.000

The excess in death rates is the greatest at the age of birth, being over 57 per 1,000, or over four times the general death rate. The importance of the excess at this age is all the more enhanced by the fact that the population at this age is greater than for any other age in any community. Hence, the absolute loss in deaths at the age of birth is much greater than at any other age.

In examining the value of this excess in death rate at any age, the relative amount of population usually found at that age should be considered. For example, the excess in death rates at age 80 and beyond is 40 per 1,000 or greater, but the absolute loss measured in number of deaths is no wise as serious as this excess indicates, because the population at this age is always very small—a little over 6 per cent. of that at the age of birth in the United States.

We have constructed Table 5 giving approximate values of the losses in deaths for representative ages, together with corresponding approximate values of the excess in death rates, taken from Table 4. The populations for each age used to compute the losses in deaths are approximate values of those given in Table II. A comparison of these losses in deaths gives a good idea of the relative importance of the excess in death rates at each age.

TABLE 5.

Age.	Population 1910.	Loss in Death Rates, per 1,000.	Loss in Deaths.
0	509,000	57	29,013 (=509.57)
1	481,000	16	7,696
10	422,000	1	422
20	471,000	3	1,413
30	390,000	4	1,560
40	313,000	4½	1,409
50	227,000	5½	1,249
60	124,000	10	1,240
70	86,000	20	1,720
80	30,000	41	1,230

With the exception of the first ten years the absolute losses in deaths in Table 5 are remarkably alike in value for each age; the losses for the first ten years, however, begin with a loss in deaths at the age of birth of almost 25 times the average loss at any following age, and decrease through a relatively large loss at age 1, to the minimum value at age 10, which is only about one fourth that of any succeeding age.

We have brought together also the expectations of life of Tables 1 and 2 in Table 6 for purposes of comparison and discussion. A third column gives the corresponding differences in these expectations, expressed in years and days.

TABLE 6.

COMPLETE EXPECTATIONS OF LIFE AS BASED UPON THE TWO ASSUMPTIONS THAT DEATHS ARE AND ARE NOT PREVENTED ACCORDING TO THE RATIOS GIVEN IN TABLE I.

Age.	Deaths		Loss in		Age.	Deaths		Loss in	
	Not Prevented.	Prevented.	Years.	Days.		Not Prevented.	Prevented.	Years.	Days.
0	49.44	62.11	12	245	45	24.68	29.28	4	219
1	56.03	66.26	10	84	46	23.97	28.47	4	183
2	56.84	66.28	9	161	47	23.26	27.67	4	150
3	56.64	65.67	9	11	48	22.56	26.87	4	113
4	56.15	64.94	8	288	49	21.87	26.09	4	80
5	55.51	64.13	8	226	50	21.17	25.30	4	47
6	54.81	63.27	8	168	51	20.47	24.52	4	18
7	54.06	62.42	8	131	52	19.78	23.74	3	350
8	53.26	61.54	8	102	53	19.09	22.97	3	321
9	52.43	60.63	8	73	54	18.40	22.21	3	296
10	51.57	59.72	8	55	55	17.74	21.46	3	263
11	50.69	58.79	8	37	56	17.08	20.72	3	234
12	49.80	57.86	8	22	57	16.45	20.00	3	201
13	48.91	56.80	7	321	58	15.83	19.30	3	193
14	48.03	56.00	7	354	59	15.23	18.61	3	139
15	47.15	55.07	7	336	60	14.63	17.93	3	110
16	46.31	54.16	7	310	61	14.05	17.27	3	80
17	45.50	53.26	7	277	62	13.48	16.61	3	47
18	44.71	52.36	7	237	63	12.92	15.96	3	15
19	43.93	51.48	7	201	64	12.36	15.32	2	350
20	43.15	50.59	7	161	65	11.82	14.69	2	318
21	42.37	49.70	7	120	66	11.29	14.07	2	285
22	41.60	48.82	7	80	67	10.77	13.47	2	256
23	40.83	47.94	7	40	68	10.26	12.87	2	223
24	40.07	47.06	6	261	69	9.77	12.29	2	190
25	39.31	46.18	6	318	70	9.29	11.71	2	153
26	38.56	45.31	6	274	71	8.82	11.15	2	120
27	37.82	44.45	6	230	72	8.36	10.59	2	84
28	37.08	43.58	6	183	73	7.93	10.04	2	40
29	36.34	42.72	6	139	74	7.50	9.51	2	4
30	35.61	41.86	6	91	75	7.09	8.99	1	329
31	34.88	41.01	6	47	76	6.70	8.49	1	288
32	34.15	40.15	6	0	77	6.31	8.00	1	252
33	33.42	39.30	5	321	78	5.98	7.53	1	201
34	32.69	38.46	5	281	79	5.64	7.07	1	157
35	31.96	37.61	5	237	80	5.32	6.63	1	113
36	31.23	36.76	5	193	81	5.02	6.20	1	66
37	30.50	35.92	5	153	82	4.74	5.78	1	15
38	29.77	35.08	5	113	83	4.47	5.38		332
39	29.03	34.24	5	77	84	4.23	4.99		277
40	28.30	33.40	5	37	85	4.01	4.62		223
41	27.57	32.57	5	0	86	3.79	4.25		168
42	26.85	31.74	4	325	87	3.58	3.89		113
43	26.12	30.91	4	288	88	3.39	3.56		62
44	25.40	30.09	4	252	89	3.22	3.27		18
					90	3.06	3.06		0

According to Table 6, the expectation of life at age 10 is, at present, 51.57 years; the expectation of life at age 10 would be 59.72 years, or a little over 8 years more than it is at present, if unnecessary deaths were prevented.

The greatest difference, however, occurs at the age of birth where it is almost 13 years. In other words, the average length of life would be 62 years or 13 years longer than it is now if it were not for the occurrence of unnecessary deaths.

Professor Fisher obtains between 14.02 and 16.2 years by means of his short-cut method; hence, we are inclined to believe that his method gives somewhat exaggerated results as a rule. We have confirmed this belief in our own mind by other examples which, however, are in no other way related to the subject of this paper and are, therefore, not given here.

We have no criticism of Professor Fisher's results themselves when we consider the conservatism used in the preparation of his table of ratios. In fact, we shall point out later that this loss in expectation of life due to preventable deaths may well be much larger than his largest value of 16.2 years.

It should be emphasized that our estimate of 12.67 years as the loss in the average length of life, due to preventable deaths, does not refer to the average person irrespective of age, but only to those at the age of birth. Professor Fisher's estimate of from 14 to 16 years upon the whole of life is the only estimate he can make by his short-cut method, and it is very easy for the average person to fall into the error indicated. The loss at any age is significant enough, but by far the greatest loss is sustained at the age of birth.

On reference to Table 6, we notice that even at age 10 the loss in expectation of life is 8.15 years, or very little over 60 per cent. of the loss at the age of birth. At age 40, the loss is a little over 5 years, or about 40 per cent. of the loss at the age of birth. The loss at each age higher than age 10 is approximately 1 year less than the loss for age 10, for each succeeding ten years.

For purposes of comparison, attention is called to the fact that it has been estimated elsewhere by means of the methods used in this paper,* that the occurrence of deaths due to

*J. W. Glover, "The Monetary Loss in the United States due to Tuberculosis, based on the Returns of the Twelfth Census," *Transactions* of the Sixth International Congress on Tuberculosis, 1908.

tuberculosis causes a loss of about $2\frac{1}{2}$ years in the expectation of life at age 20, or about one third the loss due to preventable deaths at the same age. However, this estimate is based upon the total number of deaths due to tuberculosis instead of just the preventable deaths due to that disease.

Similarly, the loss in the average length of life due to the total number of deaths due to typhoid fever has been estimated elsewhere to be about one half of one year, or about one twenty-fifth of the loss due to preventable deaths at the same age (age of birth).*

The important question naturally arises, would an assumed prevention of deaths less conservative in character than the one we have just considered lead to a little or to a much greater variation in estimates of vital losses due to preventable deaths? In other words, once we have actually decreased the number of annual deaths due to the different diseases to accord with Professor Fisher's ratios, have we accomplished all that is worth while, or have we merely begun? We shall attempt to answer these questions by the use of deductions made in connection with a discussion of Table 3.

It is to be remembered that Table 3 was constructed with death rates based upon deaths due only to unpreventable diseases. Thus, Table 3 reflects the mortality conditions of a community wherein occur no deaths due to diseases of which any percentage of deaths are at present preventable.

It is true that the assumption of such a community is too ideal to be realized for a long time in the future, but we believe this assumption can be replaced by others, less extreme in character, which would lead to results almost as remarkable. If Professor Fisher had tabulated the most radical or extreme estimates of the ratios of preventability that were given him, instead of the most conservative average of all, and if absolutely everything in the form of recent knowledge and discoveries in regard to diseases were used, we believe the results given in Table 3 would at least be approached very closely.

By the nature of the facts involved, it would be impossible to completely verify the above statement; the belief is based

* W. C. Mendenhall and Earl W. Castle, "Vital and Monetary Losses in the United States due to Typhoid Fever, QUARTERLY PUBLICATION OF THE AMERICAN STATISTICAL ASSOCIATION, June, 1911.

solely upon a personal survey of all the data used in the preparation of this paper and we shall not take the time or space to attempt to substantiate it.

In order that the main features of Table 3 might be more clearly and readily comprehended, we have brought together in Table 7 representative values of the death rates and expectations of life of both Tables 1 and 3. Columns of corresponding differences and percentages are added.

TABLE 7.

Age.	(Table 1).	(Table 3).	Differences.	Percentages.	(Table 1).	(Table 3).	Differences.	Percentages.
(1)	(2)	(3)	(4)	(4)÷(2)	(2)′	(3)′	(4)′	(4)÷(2)′
0	.134300	.006908	.127392	95.1	49.44	84.89	35.45	71.8
10	.002407	.000058	.002349	97.5	51.57	75.55	23.98	46.5
20	.005222	.000084	.005138	98.4	43.15	65.60	22.45	52.0
30	.007554	.000242	.007312	96.8	35.61	55.68	20.07	56.4
40	.009631	.000732	.008899	92.4	28.30	45.88	17.58	62.1
50	.014501	.001725	.012776	88.2	21.17	36.36	15.19	71.7
60	.028729	.003630	.025099	87.5	14.63	27.14	12.51	85.7
70	.057337	.007646	.049691	86.7	9.29	18.25	8.96	96.4
80	.12638	.02321	.10317	82.0	5.32	9.96	4.64	87.2

It is not our purpose to discuss all the results indicated by Table 7, but merely to dwell briefly upon the most important results which will help us most to answer the questions raised at the beginning of this discussion.

According to Table 7, the average length of life should be about 85 years, or about 35½ years longer than it is at the present time; expressed differently, the average length of life should be about 70 per cent. longer than it is at present.

The expectation of life at age 10 should be about 76 years, or 24 years longer than it is at present.

We can now answer our very important questions by saying that the results given in Table 7 indicate that the results obtained by comparing Tables 1 and 2 are little more than marks of a beginning of what can be done in the way of improving general health conditions.

Such results at least suggest excellent goals toward which every effort should be made to advance; the results are certainly worthy of the greatest efforts.

MONETARY LOSSES.

Our discussion of monetary losses is based primarily upon the assumption that the average person contributes something to the wealth of the community about him during the most productive period of his life.

Although practically no one will object to the above assumption, there seems to be no satisfactory way of estimating the average value of this contribution. There are many who not only contribute nothing, but are even a heavy expense to their community all during their lives; there are others whose contribution is immeasurably great. There are some who, because of ill health or poverty, are prevented from adding to the wealth of their community except at particular intervals of the period throughout which the average person is considered most productive. Only a systematic investigation into these various sets of conditions would give us any satisfactory results, and such an investigation seems never to have been made.

Many have constructed schedules of values of this contribution by ages, which are intended to fit the average set of circumstances; the fact that these schedules fail to agree very closely indicates that they are not altogether satisfactory.

We make no attempt in this paper to decide rigidly what the value of this contribution should be assumed to be; instead, we assume a purely arbitrary value and then discuss certain monetary losses in terms of this value. Those who have decided views as to what the value of the contribution should be assumed to be can then modify the results in exactly the same proportion that their choice of this value differs from the value used here.

We shall assume that the average person contributes $100 annually to the wealth of the community about him between the ages 20 and 70. Hence, the death of such a person involves a loss equal to the present value of an annuity of $100 per annum at his age for the period ending with the age 70.

The present values of such annuities for each age from 20 to 70, interest at 5 per cent., based upon Tables 1 and 2, are given in the following table:

TABLE 9.

PRESENT VALUE, AT EACH AGE FROM 20 TO 70, COMPUTED WITH COMPOUND INTEREST AT 5 PER CENT., OF AN ANNUITY OR WEALTH INCREMENT OF $100 PER ANNUM AT THE END OF EACH YEAR, UNTIL AGE 70, ACCORDING TO TABLES 1 AND 2.

Age.	Deaths		Loss in Value.	Age.	Deaths		Loss in Value.
	Not Prevented.	Prevented.			Not Prevented.	Prevented.	
20	$1,601.00	$1,705.66	$104.66	45	$1,189.61	$1,274.46	$84.85
21	1,589.88	1,695.02	105.14	46	1,163.94	1,247.11	83.17
22	1,578.45	1,683.97	105.52	47	1,137.51	1,218.79	81.28
23	1,566.72	1,672.51	105.79	48	1,110.16	1,189.40	79.24
24	1,554.75	1,660.64	105.89	49	1,081.68	1,158.83	77.15
25	1,542.58	1,648.38	105.80	50	1,051.89	1,126.97	75.08
26	1,530.17	1,635.69	105.52	51	1,020.73	1,093.73	73.00
27	1,517.49	1,622.55	105.06	52	988.11	1,059.05	70.94
28	1,504.49	1,608.95	104.46	53	954.13	1,022.92	68.79
29	1,491.10	1,594.83	103.73	54	918.94	985.43	66.49
30	1,477.25	1,580.19	102.94	55	882.76	946.67	63.91
31	1,462.93	1,564.99	102.06	56	845.57	906.58	61.01
32	1,448.11	1,549.22	101.11	57	807.37	865.14	57.77
33	1,432.74	1,532.85	100.11	58	768.09	822.25	54.16
34	1,416.76	1,515.81	99.05	59	727.38	777.64	50.26
35	1,400.11	1,498.04	97.93	60	684.89	731.03	46.14
36	1,382.71	1,479.50	96.79	61	640.40	682.21	41.81
37	1,364.55	1,460.16	95.61	62	593.66	630.93	37.27
38	1,345.58	1,440.00	94.42	63	544.33	576.92	32.59
39	1,325.82	1,418.99	93.17	64	492.12	519.91	27.79
40	1,305.25	1,397.16	91.91	65	436.69	459.16	22.92
41	1,283.84	1,374.40	90.56	66	377.52	395.60	18.08
42	1,261.55	1,350.77	89.22	67	314.02	327.44	13.39
43	1,238.39	1,326.27	87.88	68	245.51	254.50	8.99
44	1,214.41	1,300.84	86.43	69	171.13	176.18	5.05

With these present values as a basis we could compute the present value of the total losses sustained throughout the United States, if the number of deaths by causes and by ages were known for the whole country. Less than one half of our states, however, keep anything like an accurate record of deaths each year.

If these statistics of deaths were known for the whole country, we could use Professor Fisher's table of ratios to determine the number of deaths at each age that are preventable; this number multiplied by the present value of the corresponding annuity would give us a measure of the monetary loss for that age, due to the occurrence of preventable deaths.

Since these statistics are not available for the whole country, we are compelled to use another method to determine the monetary losses due to deaths that are preventable. We shall make use of the population instead of the number of deaths to determine the losses under consideration, because the population of the whole country is given every 10 years by the census.

Just as the second column in Table 9 gives the present values of the future contributions, as computed by the use of Table 1, the third column gives the present values of the same future contributions, as computed by the use of Table 2 which is based upon mortality conditions which would exist if preventable deaths were prevented.

Referring to Table 9, we see that the value of the average person aged 20 to his community is $1,601.00, and that this value would be $1,705.66 if preventable deaths were prevented. Hence, such a community suffers a loss of $104.66 on every person living at the age 20, because of the occurrence of preventable deaths.

Column four of Table 9 gives values of these differences between the present values of persons for the different ages under the two sets of mortality conditions, which may therefore be regarded as measures of the effect of preventable deaths upon the value of persons to their community at different ages.

These differences, or "loss rates" increase slightly at first as age increases, due to the peculiar combination of the expectation of life and number of survivors of the mortality tables at these ages. After an interval of about ten years the loss rates start to diminish very gradually until about age 50 and then the decrease becomes more rapid toward zero.

Since we have a monetary measure of the effects of the occurrence of preventable deaths upon the value of each living person to his community, it remains merely to multiply the population of the United States for each age by the corresponding loss rate to determine the total losses at each age due to the occurrence of preventable deaths.

These populations for 1910 are given in Table 10 together with the corresponding loss rates, and finally the total losses

themselves. The population data were obtained in quinquennial age groups from the government mortality statistics, and the population for each age was determined by Sprague's method, discussed and used previously in this paper.

TABLE 10.

TABLE SHOWING THE PRESENT VALUE, COMPOUNDED ANNUALLY AT 5 PER CENT. OF THE LOSS DUE TO PREVENTABLE DEATHS, BASED UPON THE POPULATION OF THE UNITED STATES OF 1910, BOTH MALES AND FEMALES, FOR EACH AGE AND CERTAIN AGE GROUPS BETWEEN AGES 20 AND 70, ON THE BASIS OF AN ASSUMED PRODUCING CAPACITY OF $100 PER ANNUM UNTIL AGE 70.

Age.	Population, 1910.	Loss Rate.	Total Loss.	Age.	Population, 1910.	Loss Rate.	Total Loss.
20	1,829,028	104.66	$191,426,070	45	947,320	84.85	$80,380,102
21	1,834,552	105.14	192,884,797	46	915,046	83.17	76,104,376
22	1,827,619	105.52	192,850,357	47	887,879	81.28	72,166,805
23	1,802,149	105.79	190,649,343	48	867,715	79.24	68,757,737
24	1,763,636	105.89	186,751,416	49	851,237	77.15	65,672,935
20–24	9,056,984		954,561,983	20–49	40,336,056		3,960,550,043
25	1,725,192	105.80	182,525,314	50	835,059	75.08	62,696,230
26	1,686,044	105.52	177,911,363	51	822,047	73.00	60,009,431
27	1,641,354	105.06	173,340,651	52	796,738	70.94	56,520,594
28	1,590,635	104.46	166,157,732	53	751,796	68.79	51,716,047
29	1,536,778	103.73	159,409,982	54	695,151	66.49	46,220,590
20–29	17,236,987		1,813,907,025	20–54	44,236,847		4,237,612,935
30	1,481,263	102.94	152,481,213	55	641,014	63.91	40,967,205
31	1,421,512	102.06	145,079,515	56	585,274	61.01	35,707,567
32	1,375,605	101.11	139,087,422	57	541,109	57.77	31,259,867
33	1,351,976	100.11	135,346,317	58	516,108	54.16	27,952,409
34	1,341,829	99.05	132,908,162	59	503,446	50.26	25,303,196
20–34	24,209,172		2,517,809,654	20–59	47,023,798		4,397,803,179
35	1,329,384	97.93	130,186,575	60	488,856	46.14	22,555,816
36	1,319,524	96.79	127,716,728	61	475,366	41.81	19,875,052
37	1,297,068	95.61	124,012,671	62	458,783	37.27	17,098,842
38	1,253,418	94.42	118,347,728	63	435,645	32.59	14,197,671
39	1,196,706	93.17	111,497,098	64	408,500	27.79	11,352,215
20–39	30,605,272		3,128,570,454	20–64	49,290,948		4,482,882,775
40	1,143,469	91.91	105,096,236	65	383,517	22.92	8,790,210
41	1,090,171	90.56	98,725,886	66	359,649	18.08	6,502,454
42	1,043,061	89.22	93,061,902	67	335,775	13.39	4,496,027
43	1,006,836	87.88	88,480,748	68	312,015	8.99	2,805,015
44	978,050	86.43	84,532,862	69	288,547	5.05	1,457,162
20–44	35,866,859		3,597,468,088	20–69	50,970,451		4,505,933,543

As in the case of the loss rates, the total monetary losses for the different ages increase slightly at first as age increases from about $191,000,000 at age 20 to $193,000,000 at age 22, but begin to decrease a little earlier than the loss rates. At age 23 the loss is again approximately that at age 20; from age 23 on, the decrease in the values of the losses is very gradual to the end of the table.

Besides the total losses for each age, the losses for the accumulative age groups 20–24, 20–29,—20–69 are given. The grand total, or the loss for the total ages 20–69 is $4,505,933,543. This amount may then be regarded as the total monetary loss in terms of the arbitrarily assumed contribution $100, sustained by this country because of the occurrence of unnecessary deaths.

Just as in Table 9, we have the present value, at each age, of the future contributions of $100 per annum, so we have in this grand total of $4,505,933,543 the present value of an annuity of $246,820,350 per annum to continue for 50 years, interest at 5 per cent. In other words, $246,820,350 may, in the same connection, be regarded as the total annual loss sustained in this country because of preventable deaths. Perhaps it will help to visualize the value of this annual loss to state that it is about one fourth the value of our annual wheat crop and between two and three times the value of our annual product of gold which is approximately one fifth of that of the world.

A comparison of the mortality tables in this article leads to the following conclusions.

The losses in death rates sustained by this country due to preventable deaths run from as low as 1 per 1,000 at age 10 to as high as 57 per 1,000 at the age of birth. Expressed in percentages, these losses run from 30 per cent. of the actual death rates, or less, at age 90 and above, to over 50 per cent. at age 35 and all ages below, being over 55 per cent. between ages 15 and 20.

The losses in expectation of life or average future life time are about 13 years on the whole of life, 5 years less than that at the age of 10, and approximately 1 year less than that for each succeeding ten years.

If we assume that every person contributes $100 annually to the wealth of the community about him during the most productive period of life, say from age 20 to age 70, we estimate the present value of the total future losses in this country to be about $4,500,000,000 and the annual loss to be about $250,000,000.

The estimates of corresponding monetary losses where a different value is assumed for the individual contribution are to be found by increasing or diminishing (as the case may be) the above values in the same proportion.